RECENT THEORETICAL CONSIDERATIONS ON THE RELATIONSHIP BETWEEN THE CHLORIDE CONTENT OF WATER AND THE DISCHARGE IN THE DANUBE

(Danubialia Hungarica LIII.)

by

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Flow volumes in natural watercourses and the amount of substances dissolved in the water are known to vary continuously. Several attempts have been made so far to establish a relationship between parameters characterizing hydrometry and hydrochemistry.

Previous studies on this problem were aimed at determining, for a particular gage on the Danube, variations in the *chloride content*, *alkalinity*, dissolved *oxygen*, *carbon dioxide*, *ammonia*, *iron*, *manganese*, *magnesia*, *sulphur*, *hardness*, etc. of water in terms of discharge pertaining to the time of sampling. The explicite, or implicite endeavour of these studies was to demonstrate the *uniqueness* of the relationship between the foregoing parameters. Random errors of observation, or other unforeseen disturbing influences were offered as explanations for occasional discrepancies of the results. Yet in spite of the compromises made in accuracy, a correlation better than 60 to 65% closeness could not been detected between the above variables.

Aside from simple relationships *composite* relationships also frequently encountered in hydrology. Since relationships of about 60% closeness should not be accepted as satisfactory, the possibility of a composite relationship between hydrometry and hydrochemistry could not be excluded.

As is well known from the *hydrology of natural watercourses* the same discharge is conveyed at rising stages at a lower depth than in the case of falling stage. The hydrograph representing variations of discharge in time shows in fact a peaking time before that of the hydrograph representing stage variations. By plotting discharges in terms of stages pertaining to identical time, i.e., by introducing time as a parameter, rather than as one of the coordinate axes, a *looped* curve is obtained, on which generally two stages instead of one pertain to any particular discharge value (Fig. 1).

A familiar method in *hydraulic model testing* consists in "*marking*" water with the solution of a chemical substance, or dye, in order to observe the movement of "tagged" water particles among the "untagged" ones.

The tagged water particles in occupying the position of untagged ones were found to suffer occasional delay and the progressing changes in hydraulic

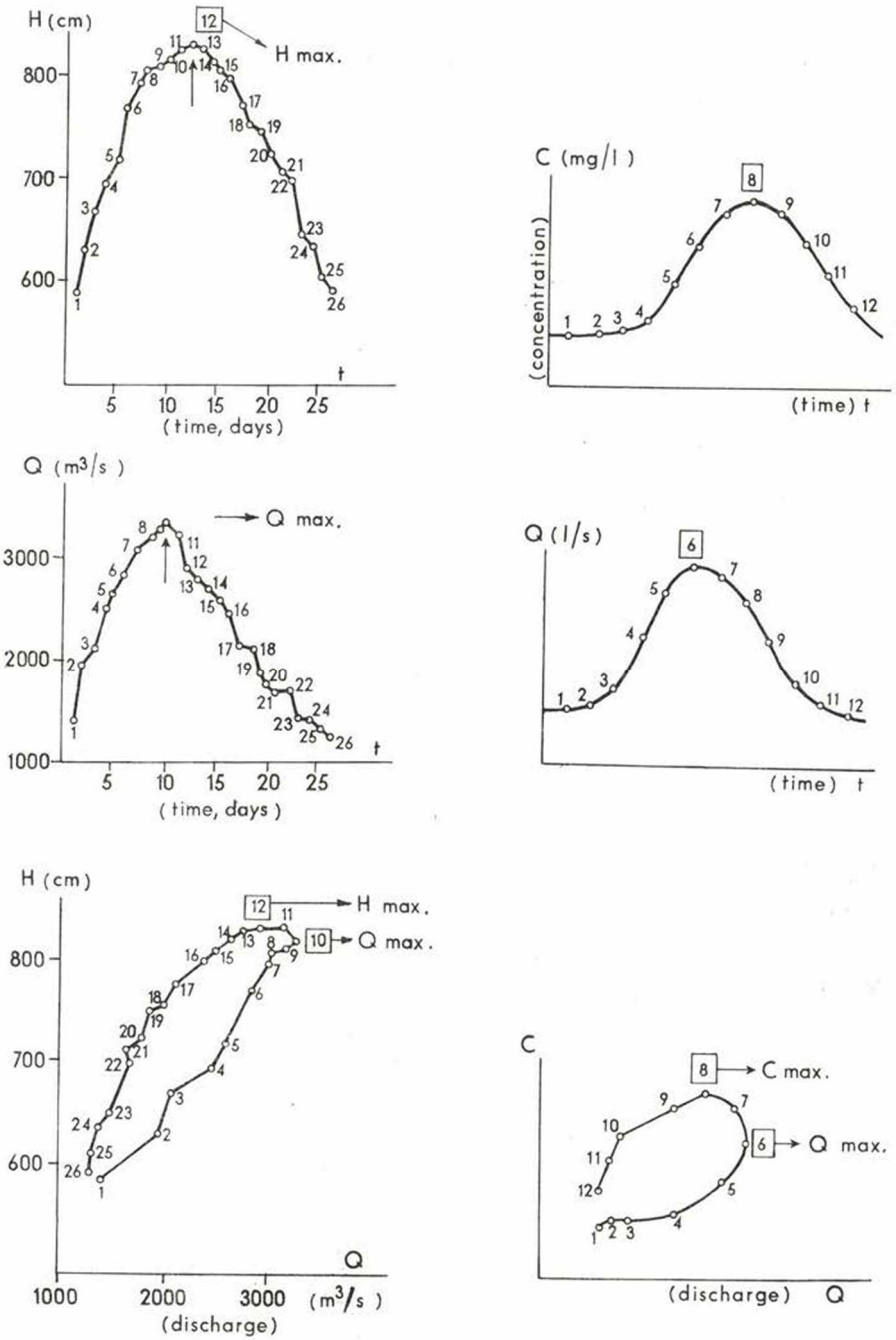

Fig. 1. H vs. t, Q vs. t and H vs. Q plots

parameters may advance before the actual progress of water. By plotting the relevant parameters — dropping out time curves — directly in terms of each other, a closed loop curve is again obtained (Fig. 2).

As a generalization of the above observations it should be noted that by plotting ordinates of wave curves (sine-, cosine waves) directly as functions of each other displaced relative to each other closed curves are obtained. As demonstrated mathematically by N é m e t h (1954) these curves are considered ellipses, or circles (Fig. 3) in this particular case.

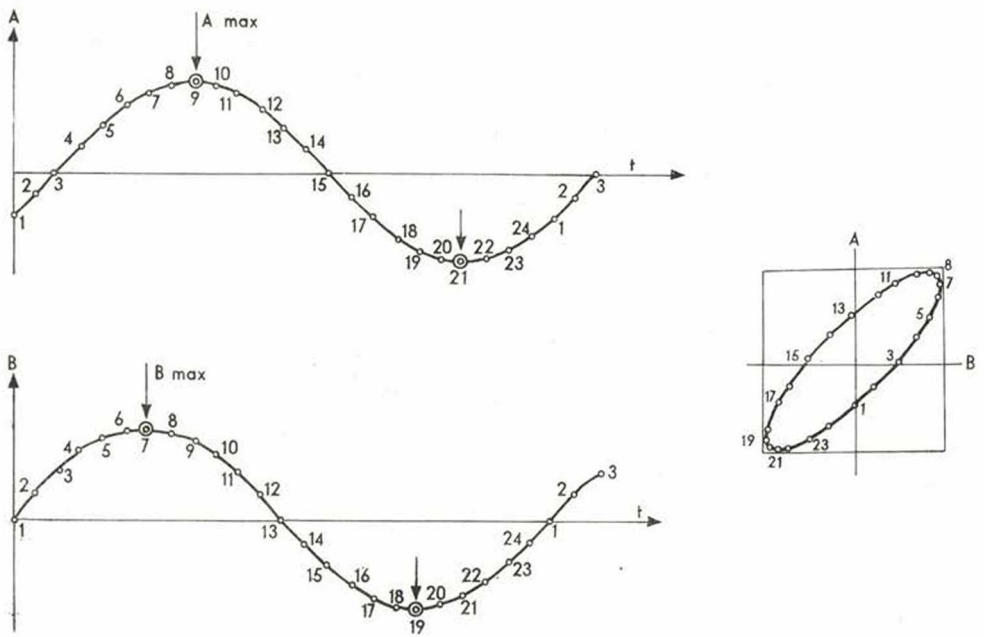

Fig. 2. C vs. t, Q vs. t and C vs. Q plots

The *composite relationships* represented by the closed loop curves are essentially *regime relationships*, since their definition included the time of occurence, i.e., *the sequence of the times at which they occured.*

When considering the relationship between discharge and dissolved substances the concentration in the Danube, the neglect of the regime character would amount in the authors' opinion to the neglect of the essentials of the phenomenon itself.

Observations made during a *series of flood waves* which passed down the Danube in 1965, as well as the evaluation of these data are quoted in order to substantiate the theory outlined above. To eliminate disturbing influences on the results, *variations of chloride content* will only be considered here. The advantage accuring therefrom is that by adopting this parameter, which is least

sensitive to the activity of aqueous organisms and pollution, the most suitable possibility was approximated for deriving conclusions of fundamental character.

Between March and July 1965 altogether 7 flood waves of different magnitude passed through the Budapest gaging cross section of the Danube. Of these the second, sixth but especially the seventh were of outstanding magnitude. From the plot showing variations of *discharge* and *chloride content*, as well as *regime relationships* of the same (Fig. 4) — completed with data pertaining to a flood wave in 1966 — the rising and falling branches will be seen to be separated also in the relationships of discharge and chloride content.

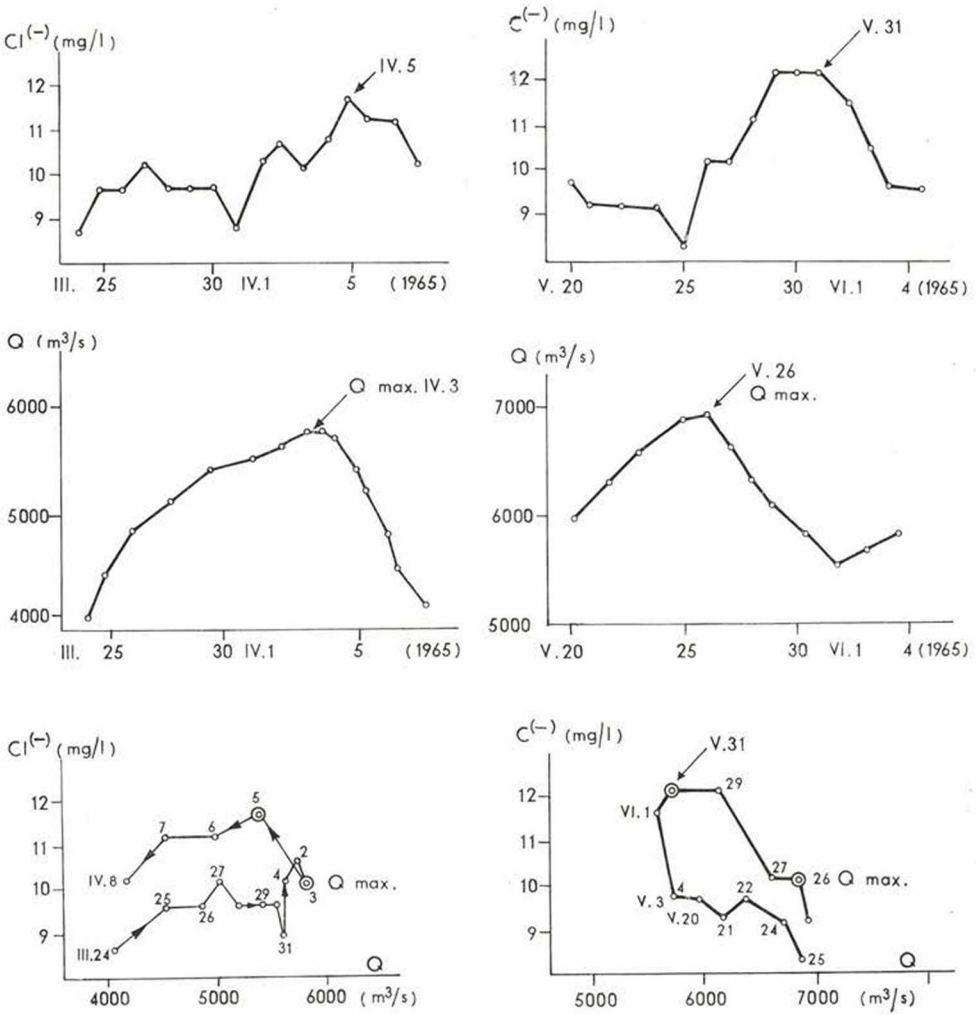

Fig. 3. *A* vs. *t*, *B* vs. *t* and *A* vs. *B* plots

The relationships can be represented by a *loop curve*, indicating their *composite character*, also as far as the discharge-chloride content relation is concerned. The difference between the peaks of the time curves makes the relationships shown in Fig. 4 similar to the examples illustrated in Figs. 1 to 3.

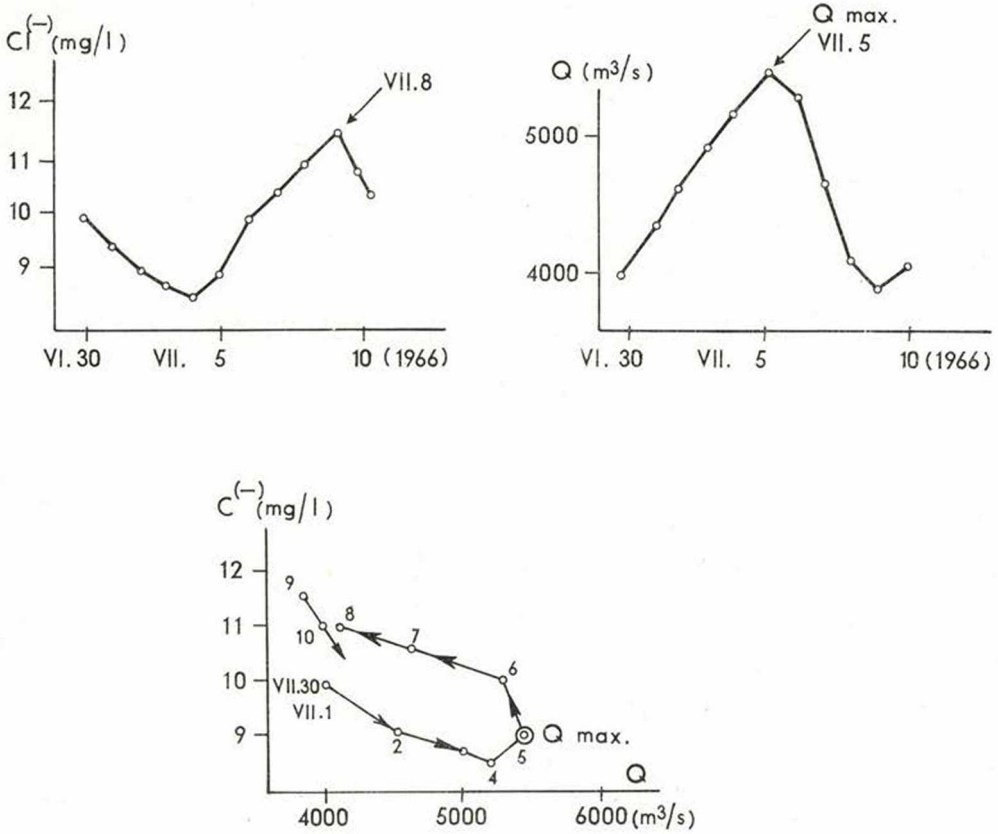

Fig. 4. Chloride concentration *vs.* time, discharge *vs.* time and chloride concentration *vs.* discharge plots during three flood waves of the Danube

a) Flood wave No. 2 in 1965
b) Flood wave No. 6 in 1965
c) Flood wave in 1966

An additional conclusion to be derived from these results is that owing to the dominant role of hydrological factors, formal and simplified mathematical means are not applicable to every phenomenon in Nature. Mathematical tools should always be adapted to the fundamental character of the phenomenon which they are intended to describe.

Summary

A catastrophic flood, higher than ever recorded has passed in 1965 the Danube, second largest river of Europe. A detailed experimental and theoretical analysis of the connection between discharge and chloride content of the water during this (and, the lesser 1966) flood periods has shown that the relationships between these two parameters can be represented by single or multiple loop curves, indicating their composite character.

REFERENCE

Németh, E. 1954. Hidrológia és hidrometria. (Hydrology and Hydrometry.) Budapest. p. 662.